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# PROJECT PIMO FINAL REPORT

## PIMO OPERATIONAL SYSTEM ANALYSIS

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SERENDIPITY, INC.

## FOREWORD

This report (Volume I through Volume VIII) represents the final phase of a study and test which was initiated in September 1964 to explore newly developed techniques and devices for presenting T. O. (Technical Order) type instructions and information. The eight volumes of data contain the result of a test conducted in an operational environment using concepts developed during an earlier phase under Contract AF 04(694)-729 and documented in BSD-TR-65-456. Both the early phase and final phases which were accomplished under Contract AF 04(694)-984, Project 1316, "Presentation of Information for Maintenance and Operation (PIMO)", were started in June 1966 and completed in April 1969. This final report was submitted in May 1969.

The original program documentation was prepared by Mr. C. L. Schaffer, SMTE, in 1964. He subsequently functioned as the Air Force Program Director and Chairman of a Working Group which monitored all development throughout the life of the project. This Group was composed of individuals from various Air Force commands (AFLC, MAC, ATC, ADC, AFSC) and the Army Command (AMCPM, AXMLE) knowledgeable in the various maintenance disciplines and all facets of the T. O. system. Capt. Don Tetemeyer, the Project Scientist during the formulative stages of the Program was largely responsible for the basic test structure. Mr. John Saunders was the monitor for all contractual aspects until his reassignment in 1968.

Any success one may attribute to the project must be shared by numerous individuals; however, major credit and appreciation are due General Howell M. Estes, Jr., Commander of the Military Airlift Command, who provided the C-141A aircraft and the bases at Charleston, Dover and Norton for the operational test. Sharing in the credit for the MAC contributions are Lt. Col. Don Watt and his staff at Hq. MAC, and Col. Foreman, Col. Henzi, W/O Van Riper and all the personnel at Charleston Air Force Base and also at Dover and Norton who participated in the test. The hardships imposed on their organizations are recognized, and we sincerely appreciate the special efforts put forth to overcome all obstacles. The test could never have been conducted without the cooperation and competent performance of these many individuals.

We are especially indebted to the Air Force Human Resources Laboratory, Wright-Patterson Air Force Base for their financial contributions at a critical point in the project; and also to the Army Materiel Command, who believed the test potential of sufficient magnitude to warrant the expenditure of their funds. We are most grateful for their confidence and assistance. It is most assuredly the primary factor that permitted completion of the test.

This technical report has been reviewed and is approved.

D A Cook

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## ABSTRACT

This report describes the latest phase in the program to develop and evaluate PIMO (Presentation of Information for Maintenance and Operation); a job guide concept applied to maintenance. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Three immediate behavioral effects were expected: 1) reduction in maintenance time, 2) reduction in maintenance errors, and 3) allow usage of inexperienced technicians with no significant penalty. Experienced and inexperienced Air Force technicians performed maintenance on C-141A aircraft using PIMO Job Guides presented in audio-visual and booklet modes. Performance was measured in terms of time to perform and procedural errors. The performance was compared with the performance on the same jobs by a control group, i.e., experienced technicians performing in the normal manner. The following conclusions were drawn from the test results: 1) after initial learning trials, both experienced and inexperienced technicians using PIMO can perform error-free maintenance within the same time as experienced technicians performing in the normal manner, 2) inexperienced technicians perform as well as experienced technicians when both use PIMO, 3) there is no significant difference between audio-visual and booklet modes, 4) the users revealed an overwhelmingly positive reaction to PIMO, and 5) the performance improvements provide the capabilities to significantly improve system performance defined in terms of departure reliability, time-in-maintenance, and operational readiness. This report also presents a description of the recommended operational system, specifications and guidelines for PIMO format development, including troubleshooting.

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## INTRODUCTION

### A. GENERAL

With the coming of age of complex weapons systems, a requirement arose for a modern, efficient presentation of technical information relating to the maintenance of those systems. Project PIMO (Presentation of Information for Maintenance and Operation) was let by the Air Force to Serendipity, Inc. to research and develop a means to satisfy this requirement. This research led to the development of new concepts for presenting maintenance information. This volume describes the system which evolved during Project PIMO.

### B. PIMO CONCEPTS

Two separate modes of presentation of maintenance information were investigated.

#### 1. Print Mode

The first of these modes was that of printed booklets comprised of short, simple maintenance steps and informative pictorials for each step. The method of expressing instructions was standardized and the vocabulary was limited to the users' language to ensure comprehension. A highly stylized pictorial drawing technique was developed which controlled the amount of information included to that amount needed for the associated instructions.

#### 2. Audio-Visual Mode

The second mode of maintenance information presentation was audio-visual. In this mode, the pictorials which were used in the booklet were presented visually, while instructions were given by voice narration.

## C. PIMO EVALUATION

In order to make a valid evaluation of the relative effectiveness of the two presentation modes, a comprehensive field test was conducted. Once the materials for both modes were developed, their relative effectiveness was evaluated in operational setting. PIMO concepts were tested on an operational aircraft maintenance system (C-141) with actual maintenance performed following PIMO procedures.

## D. CONCLUSIONS

### 1. Test Results

The test results show that when PIMO formatted data are used, apprentices with and without specialist training can perform better than specialists using conventional Air Force technical manuals. In fact, these apprentices can perform better than the highly-trained and experienced specialist performing without any data. This would tend to indicate that the training for first term enlistees can be drastically reduced. They can be assigned to maintenance bases with minimal training, and therefore be productive during most of their enlistment term. Specifically a 25.8% increase in productive utilization may be realized if just the customary O.J.T. is eliminated. An even greater increase may be realized if technical school time -- 6 months -- could be shortened. The test yielded evidence that the use of PIMO allows for such a course truncation.

In the event that the technician demonstrates proficiency and willingness to remain in the service, he then can be sent to specialist training. Specialist training will still be required since the job guides cannot cover all activities. Moreover, PIMO Job Guides will facilitate specialist performance when they are assigned to new aircraft.

Maintenance personnel using PIMO data in both the print and audio-visual modes performed error-free. The performance time difference between the two modes was insignificant. Thus, the print mode was selected as the recommended one for operational deployment.

## 2. Potential Savings

Simulation studies using the AMES (Aircraft Maintenance Effectiveness Simulation) Model indicate that significant improvement in such system level parameters as departure reliability, time in maintenance, and operational readiness can be realized simply by using apprentices and non-specialists for what is currently reserved for specialists. This potential will be realized only if the maintenance managers are willing to assign these non-specialist people to jobs which they can perform adequately when PIMO Job Guides are available.

In conclusion, it can be seen that PIMO represents: 1) an important step forward in the technique of data presentation; 2) a means of improving aircraft maintenance; and 3) a means of obtaining more productive utilization of Air Force maintenance personnel.

## 3. Data Usage

Many argue that the technicians will use any set of data if enough pressure is applied. However, evidence accumulated by our experience in examining maintenance by different individuals, at many different bases, for different commands, indicates otherwise. Data usage appears to be an exception rather than the rule.

Serendipity observed and reported in an earlier phase of the PIMO study that use of conventional manuals was less than 5 percent. Observations made during the current test indicated that usage continues to remain considerably less than 5 percent. A study conducted under the auspices of the Aeromedical Research Laboratory at Wright-Patterson Air Force Base, tended to verify these observations.

These results are not surprising and certainly should not be construed as a condemnation of the conventional manuals. The manuals are not designed (nor required to be designed) for use on the job. It should not be surprising, therefore, to find the manuals are indeed not used on the job. The extent to which the manuals are used off the job is not known.

The PIMO test results indicate that technical manual <u>requirements</u> should now be changed so that manuals will be designed for use on the job, by both experienced and inexperienced technicians.

The technicians appear to have a very strong bias against using data on the job. In fact, we have seen at least one occasion where a crew chief refused to use a technician simply because he brought technical data along with him. There appears to be a general tendency to "look down" upon any individual who "has to use data to perform the job". During the earlier portions of PIMO, when the test was conducted at three different bases, we were operating under the strict definition of non-interference. Therefore, the technicians could only be encouraged to use the data, i.e., they could not be <u>required</u> to use it. Under these circumstances, the percentage of people who actually used the data was approximately 20 percent. Although this figure is significantly higher than the use of the conventional manuals, it was still not adequate. Those exposed to the data expressed positive acceptance, but still the usage was relatively low. Part of the low usage may be attributed to the fact that only 5 levels were assigned to the jobs. Most of these technicians felt they knew the job and therefore did not need technical data. On the other hand, in the test conducted at Charleston, both usage and acceptance were significantly higher for the specialists as well as the apprentices. The difference seemed to be that in Charleston, considerable time was spent working with the technicians in an attempt to get them to overcome whatever bias existed. It also is likely that seeing the apprentices perform effectively with the PIMO guides contributed to the acceptance by the specialists. The more important point is, that the specialist did accept the job guides and it was not necessary to apply any "muscle".

It can be anticipated that if job guides are delivered to a base heretofore unfamiliar with PIMO, usage will be higher than in the case of conventional manuals, but will not be sufficiently high to realize the full potential of the guides. Therefore, it is strongly urged that a carefully developed program of orientation, training, and public relations be developed before implementation.

## E. OPERATIONAL SYSTEM

This volume presents a general description of the requirements and basic characteristics of the PIMO operational system. The description is maintained at a relatively general level only, since details of both the requirements and characteristics of the system are provided in associated volumes.

It was originally anticipated that the system to be included in this volume would be an operational audio-visual system. Thus, it was anticipated that the content of this document could adhere very closely to the format requirements of ASFCM 375-5 for systems specifications. However, these specifications apply primarily to hardware or equipment systems. The system recommended from the PIMO Program is a visual-only system, using booklets as the basic means of implementation for the initial applications. There is a growth potential with respect to mechanization of the presentation means and proceduralizing of trouble-shooting. However, the system recommended is a non-hardware system. Adherence to a format for writing equipment systems specifications would not foster effective communications. Therefore, a specification format was not used for this document.

The booklet system recommended for immediate application is essentially the booklet system used in the test program. Details of the booklets concerning usage and production are described in companion documents. Therefore, the description in this volume is restricted to presentation of the requirements and the characteristics in system terms.

Alternative systems such as an audio-visual system or a mechanized system are not presented, since the data from the test would not justify immediate applications of such systems. Furthermore, the detailed design of such systems, in view of the results of the test, would not have been cost-effective for the PIMO program. This should in no way be construed to mean that further exploratory development efforts

should not be conducted with respect to mechanization, audio-visual presentations in selected areas, and proceduralizing troubleshooting. In fact, these exploratory and advanced development efforts are highly encouraged. In view of the results from the test which indicate the tremendous improvement in system performance that can be realized by providing better aids to the technicians, further development efforts in those areas are recommended.

1. Basis for Selection

The selected visual-only system was based primarily on the results of the PIMO tests. It was anticipated that detailed trade studies would be required if the original projection of the advantages of the audio-visual system had been confirmed in the test. Since it had not, detailed trade studies with respect to mechanization means for audio-visual presentation were not deemed necessary. The purpose of the following discussion is to present the basic rationale for the selection of the visual-only and booklet systems for application.

a. Visual-Only over Audio-Visual. The PIMO field test revealed no practical difference between performance supported by an audio-visual presentation compared with the performance supported by the booklet presentation. There was some indication that learning was faster at the outset when using the audio-visual mode of presentation. During early exposures to a specific job, it is believed that the audio-visual presentation provides a more "complete" presentation of the tasks since both visual and audio information are presented. This is thought to be the reason for the faster initial learning. After the technician becomes familiar with the job, it appears the fixed rate of presentation of the audio information tends to inhibit him. He is able to glance at the narration of a booklet presentation and obtain the total information for that task faster than he can get that information through the audio channel. This is probably the reason why the PIMO pilot test indicated that the audio-visual would be superior with respect to performance time.

Evaluation of the test results indicates that in those cases where it is important for the technician to have both hands free or where faster learning is important, an audio-visual mode of presentation should be considered. However, as a general job guide system, the visual mode appears to be more applicable.

The results of the test in no way should be construed to mean that the audio-visual mode of presentation should be eliminated. In fact, the results indicate a very high potential for selected usage of the audio-visual mode of presentation, either for selected jobs or for on-the-job-training. The audio-visual mode of presentation may also be particularly useful in circumstances where the individuals doing maintenance are not familiar with the written language or have a very slow reading rate. Considerations of the audio-visual mode of presentation should be given for maintenance conducted by non-English speaking populations.

b. Booklets Over Visual Device. Use of booklets rather than visual devices for presenting the visual-only information is recommended at this time. Factors other than technician performance dictate this recommendation. The booklet means of presenting the visual-only or job guide information is adequate for guiding the technician performance. Factors which support the usage of visual devices are basically storage and update. There are cases when retrieval is an important consideration. Generally, this is limited to situations where the specific item of information required for any portion of a job cannot be determined before the man starts the job. In the maintenance situations addressed on this project, the jobs are assigned and specified before the technician goes to the work site. Consequently, the specific item or items of information required can be determined before work starts. In other words, the total data base need not be accessible to the technician while on the job. The portion of the data base required is isolated to one or a few

maintenance activities. In this case, the booklet means of presentation is adequate with respect to retrieval. The booklet is certainly less expensive than a visual device.

The format is adaptable to any of the mechanization means currently on the market, including such mechanized systems as RAPID (Grumman), WSMAC (McDonnell-Douglas), MICRONS (Army), Video file (Ampex), CARD (Houston Fearless), and Recordak (Kodak). We are not stating that visual presentation devices should not be used. We are only saying that the format is the most critical aspect of the job guide. If devices are to be used, the format should not be sacrificed. Furthermore, the usability of the format for a job guide should not be degraded significantly through the use of presentation devices for purposes of improving storage, updating, and/or retrieval. This means that particular attention must be paid to such factors as portability, ease of retrieval, and resolution.

## SECTION II

## GENERAL SYSTEM REQUIREMENTS

The basic requirements addressed by Project PIMO were dictated by the goal of developing an information system which is optimum for the hardware and personnel of current and future military services. Military hardware grows more sophisticated every year while the persons who are recruited to maintain the equipment remain relatively static in their physical and mental capabilities. The means currently employed to prepare personnel to maintain this complex equipment is extensive, formal and on-the-job training. This training is expensive in itself and seriously limits the productivity of first term enlistees. The PIMO test confirmed that an improved maintenance information system can guide relatively unskilled technicians in performance of complex maintenance tasks, thereby saving training costs and increasing the productive portion of first enlistments.

The general requirements which led to the PIMO system described below relate to the characteristics and needs of the using technicians. Technicians require information on-the-job to perform properly. A key requirement of the PIMO system is the information available in visual form rather than in the head of the technician. Furthermore, the information must be usable though the technician has been given only general familiarization instruction on the system on which he is working. The single exception to this requirement is the troubleshooting maintenance function. Troubleshooting requires specific, relatively extensive understanding of the system and its theory of operation. For all maintenance, the information must be usable by personnel with an average education of tenth grade.

The information must conform to the equipment configuration on which the technician is working whenever critical to personnel or equipment safety.

Where safety is not impacted, the information should be as up-to-date as practical. The measure of practicality is the tolerance of users. Users will accept some out-of-date information and still use the PIMO data as job

guides. Eventually their tolerance ends and they will not use the data as job guides. This destroys the entire intent of the PIMO system.

The system should be convenient to use in the actual work environment. It must be within the tolerance of the users. Factors of usability which must be observed include: portability, information accessibility, readability.

The system requirements are expressed below in terms of basic system parameters. Since the quantitative values for these values will vary from system to system that the job guide system is to support, few quantitative values are specified.

1. Information Content

The Job Guide System shall provide all the necessary information required for each task in a total maintenance job. The task information must be immediately accessible to the user without requiring undue search efforts on his part. Generally, undue search efforts may be defined as locating information in more than one page or frame. The information must be easily readable by an average technician with a maximum of a tenth grade education and with only a general familiarity with the system of concern, such as knowledge of general location of major equipment groups, general knowledge of nomenclature, and familiarity with standard tools. The task information must provide not only "what to do" information, but also "how to do it" information. The information shall be explicit.

2. Scope of Coverage

The scope of coverage shall be compatible with the training program and supply concept. For example, maintenance activities occurring with a very high frequency may be better handled through training. Then the technician will know how to do the activity before he is first assigned to that activity. Such training is appropriate only for jobs which occur at sufficiently high frequency that inefficiencies in the conduct of the jobs could result in a significant impact on maintenance

effectivity. Studies have shown that approximately 30 to 40% of the total data base will cover approximately 80 to 90% of all maintenance activities. Consequently, emphasis should be concentrated on the 30 to 40% of the data occurring with the greatest frequency. The maintenance activities occurring less frequently but covering the remaining 10 to 20% must also be examined very closely. Inadequate performance for these activities may have a significantly adverse effect on the object system of concern, despite the low frequency of occurrence. Each of these activities must be examined separately for each object system. It is important to keep in mind that for jobs occurring relatively infrequently personnel require the greatest support due to the infrequent occurrence. On the other hand, the cost of developing the data may far outweigh the benefits of the data. As a general rule, maintenance instructions for equipment items failing with relatively low frequency should be included. Supportive data, such as wiring diagrams and complex schematics, should be examined very carefully before a decision is made to include them, since the cost of developing such data in addition to normally available engineering data may not be warranted when one considers the potential value. Instructions which provide specific information to the user on how to conduct maintenance are always useful if failure does occur.

3. Accessibility of Data

The accessibility of data shall be compatible with the work situation and the "normal" pauses in the work. For example, more time is available to access the information when a job is first assigned or when an activity is first assigned than when gaining access to a specific task. The effort required of the user to obtain the information at any level shall be kept to a minimum. The minimum can be defined as a limit of one or two commands or search of a well-organized index, or a search equivalent to scanning of no more than seven items presented in an unstructured manner.

More time can be allowed for finding the information relevant to an assigned job or activity. The maximum time to find the information relevant to a job is anticipated to be one minute. This should apply whether the search is manual or automatic. The maximum time allowed for searching for the information relevant to a given activity should be 30 seconds. The maximum time allowed for finding the next task in a sequence should be three seconds. It is very important that all the information relevant to a given task shall be readily accessible without undue search effort on the part of the user. Undue search effort is defined as any effort requiring a search of more than one page or frame, or two or more commands to obtain the necessary information. Data must be designed so that errors in accessing the information at the task level (reading or other forms of receiving the information) shall be near zero. One repeat or re-read is permissible if the frequency is relatively low. Regardless of the frequency, two or more repeats or errors in reading or receiving are not acceptable.

4. Portability

All the information relative to a given job or activity should be easily carried by the user along with the other things he must carry, such as a tool box. The term "easily carried" can be defined as 15 pounds or less of compact size. The PIMO field test indicated that even 12 pounds are not perceived positively by the users. The data must be carried easily under awkward working conditions, such as climbing ladders, working in cramped quarters, or walking on slippery surfaces. The ideal portability is when the user can slip the unit of concern into his pocket or tool box. Any larger size or weight should be viewed in terms of the additional benefits accrued or penalties paid.

5. Usability

The packaged data shall be useful within the available work space and environment. Available work space could be equivalent to working in the cramped quarters of the nose wheel well, avionics bay, or the

vertical stabilizer. Adverse environment includes rainy weather, low ambient illumination conditions, high noise conditions, extremely cold weather, and extremely hot and humid weather. The visibility of the information should be equivalent to, or no significant degradation from, the normally printed word read at the distance of 18 inches. Normal human engineering standards can be used for letter size and line widths. However, consideration must be given to ambient illumination conditions, as well as the format.

6. Reliability

The packaged unit of information shall be available for usage whenever the demand arises. In other words, the availability of the information must be near 100%, regardless of whether this is achieved through no failure, through redundant packaging of the data, or through redundant units. This reliability applies primarily to the 30 to 40% of the data base which covers approximately 80 to 90% of all of the maintenance actions. The stringency of the reliability requirement can be relaxed somewhat for the other 10 to 20% of the data base which are demanded at a much lesser frequency. The specific reliability requirement should be determined for each object system of concern since it will depend on the criticality of the subsystem or item.

7. Configuration

The 30 to 40% of the data base covering 80 to 90% of the maintenance actions shall not be out-of-date for any period exceeding 24 to 48 hours. This also applies to all information relevant to activities critical to equipment or personnel safety. The requirement for currency for the remaining portion of the data base can be relaxed somewhat, but should be specified for each object system of concern. The specification should be based on the expected need for the data to assure that the data configuration is up-to-date whenever the data are demanded. It is important to note that whether the data are up-to-date or not is irrelevant when the data are not being used. The critical aspect of data

configuration is when the data are demanded for use. The specific percentage of the time that the data must be up-to-date when used cannot be identified in a general sense. This must be determined specifically for the failure of each object system of concern and also to some extent on the availability of the experienced technician who can perform the necessary jobs without data when needed. The availability of such personnel, when the occurrence of such demands are relatively low, could result in a far lower frequency of updating. On the other hand, (such as in off-shore bases, where the availability of these personnel is limited, ) the percentage of the total data base which must be up-to-date at all times increases significantly. The reason for the increase is that one must assume that the job cannot be completed satisfactorily unless the data are up-to-date.

## SECTION III

## GENERAL SYSTEM CHARACTERISTICS

The print mode of information presentation was determined to be optimum from the PIMO field test. Two basic subsystems are required for the print mode: the development and update segment, and the field segment. The segments are equally important and closely interrelated. The basic intent of the PIMO system is to guide maintenance technicians in their work. To succeed in this intent, the data must be available to the technician, accurate, consistent, up-to-date, and designed for his specific characteristics. Figure 3-1 shows the relationship of the two segments.

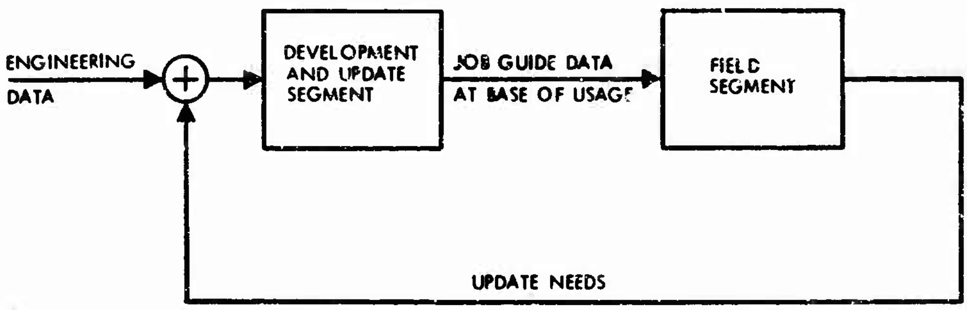


Figure 3-1. Top Level PIMO Operational System

### A. FIELD SEGMENT

The field segment involves storage, retrieval and presentation of PIMO data. Section IV of this volume describes the field segment in detail.

PIMO data are comprised of maintenance instructions and troubleshooting aids. The maintenance instructions are step-by-step proceduralized instructions for conducting a task. They include input conditions and location information. The maintenance instructions for PIMO were

developed after extensive experimentation and evaluation of basic communication principles and definition of the needs of the user.

The PIMO approach requires the language used in the text be understandable without question to inexperienced technicians. Selection of verbs is of prime importance in ensuring understandability. Project PIMO developed a list of verbs suitable for technicians maintaining the C-141A. The list was based on words which the specific technicians had often been exposed to in training. The validity of the list was determined by a suitable test of understandability.

The volume of information on a particular space is an important contributor to readability. A thorough review of psychological and communication literature indicated that there is a limit to the number of pieces of dissimilar information which a person can remember reliably. The literature showed that three items of information was the maximum for reliable temporary memorization. A limit of 20 to 25 words for these three items avoids degrading the reliability.

PIMO determined an optimum sentence structure to ensure effective communication to inexperienced technicians. For maintenance instructions, the second person imperative mood is used. Warnings and Notes are presented in the third person indicative.

The number and quality of illustrations plays a key role in effective job guides. A PIMO illustration shows the reader where a piece of equipment is, what it looks like, and what it is called. The number of callouts on a PIMO illustration is limited to seven. A person can quickly find one item in seven. As the number of callouts increases, the utility of the illustration decreases. PIMO illustrations are simplified to the extent that only the necessary information is presented. The illustrations are immediately adjacent to the step-by-step instructions.

Troubleshooting is a difficult maintenance function generally reserved for experienced personnel. PIMO includes maintenance dependency

charts (MDC), symptom-cause diagrams, narrative procedures and integrated schematics to aid these experienced technicians.

Significant attributes of the troubleshooting materials are presented below:

1. A preliminary information sheet containing:

   a. Available test equipment

   b. Preparatory procedures

   c. Aircraft configuration data

2. A maintenance dependency report possessing the following attributes:

   a. Permits a controlled exercise of system

   b Illustrates dependency of system elements upon other elements

   c. Segments system into "bite-sized" groupings of elements

   d. Graphically displays specific output states directly related to specific input states

   e. Graphically reveals system "troubleshootability"

   f. Is beneficial to design process

   g. Is amenable to computerization.

3. An integrated schematic diagram showing:

   a. All functional relationships within the system

   b. Identifiers on all elements and interconnecting circuitry.

4. Parts location illustration (when needed) showing:

   a. Parts interrelationships

   b. Parts location

   c. Part Number/Nomenclature

5. Functional description

Maintenance Dependency Charts, when supported by supplementary maintenance data, offer several advantages to the troubleshooter:

1. They show, graphically, the interdependencies within the equipment. In other words, they show how one equipment element related to another, in proper equipment operation.

2. They show all significant check points, and the proper indication at them, necessary to troubleshoot the equipment.

3. They present a general strategy for fault isolation, yet do not constrain the user to a fixed sequence of steps. They can be efficiently used by the initiate as well as the experienced technician.

The MDC is a simplified version of the SIMMS charts. This format was selected after an evaluation of all available troubleshooting guide concepts.

The recommended PIMO system stores and presents maintenance technical data in print form. The maintenance instructions are presented in small booklets (5 by 6-1/2 inches) for ease of handling by technicians. Troubleshooting aid material is stored and presented in 11 by 17 inch books. PIMO data are retrieved manually. The order of search for maintenance instructions is guided by an index which leads the user to the appropriate volume, activity and finally page. The basis of search for troubleshooting aids is either a symptom squawk, system squawk or a no-go on a checkout.

## B. DEVELOPMENT AND UPDATE SEGMENT

The development and update segment involves:

1. Preparation for development

2. Development

3. Production

4. Development and Production Control

5. Update

Section V of this volume describes the development and field segment in detail. In addition, Volumes IV through VIII of this report give detailed specifications for the Job Guide and guidelines for its preparation and control.

A highly effective scheme for preparation for development has been formulated for PIMO. This scheme involves use of common nomenclature so that all who are working on the development are communicating with each other properly. A logical technique (partitioning) is used to define the boundaries between subsystems for the purpose of maintenance. A matrix of equipment and maintenance functions is used as a management tool in preparing for development of the data. Source material is collected, collated and referenced to the function by end item matrix. Personnel are oriented to the over-all job to be performed and trained for their specific tasks. The specifications and guidelines are used for this purpose.

The development process involves definition of each maintenance step, a technical validation of each step, formatting of the data and a verification that the formatted data meets the specification and is technically valid.

Production involves typing, illustration, printing, collating and binding of the booklets.

The production of voluminous maintenance data can create a severe management problem. A computer program was developed and is used to simplify maintenance data production control. During the development of the maintenance data, significant points in the production process are monitored. Surveillance may be maintained over any specific breakdown of functions or equipment. The program provides data as to the loads and queues at individual points of the production cycle.

The large volume of maintenance data required for aircraft systems and the high rate of changes in that data due to changes in maintenance approach or hardware design impose severe problems in keeping the data up-to-date. A computer program was developed on project PIMO and is used to facilitate rapid updating of technical data. This program has the capability of storing all information pertinent to system maintenance. Such data includes identification of end items, special tools, test equipment and engineering data, maintainability data, reliability data, checkout procedures and so forth. As changes occur in the system or in its maintenance, the rapid access query system of the program provides specific information as to the effect on the maintenance data.

## SECTION IV

## CHARACTERISTICS OF THE FIELD SEGMENT

The booklet system is divided into two separate types of data. One type of data supports troubleshooting only. The second type of data supports other maintenance functions such as Checkout, Remove, Install, and Adjust. This type of data is referred to as maintenance instructions. Troubleshooting data is termed troubleshooting aids. Maintenance instructions apply to those maintenance functions not included in the test, such as the "look-see" portion of scheduled maintenance as well as to shop activities. However, the current system is limited primarily because of limitations of the test to on-aircraft maintenance covering the basic functions of Checkout, Remove, Install, and Adjust (for the maintenance instructions), and for the troubleshooting function (by the troubleshooting aids). The basic troubleshooting aid is a modified version of the SIMMS package and is considered to be an integral part of the total PIMO booklet system.

### A. MAINTENANCE INSTRUCTIONS

The maintenance instructions portion of the job guide system covers any maintenance function which can be supported by procedures established in advance. This could eventually apply to troubleshooting, although this approach was not selected during the early phases of PIMO. It is important to note that the basic characteristics of that portion of the job guide system covering maintenance instructions do in fact apply to any job amenable to proceduralization.

#### 1. Information Content

The PIMO Job Guide System provides information basically at the task level. A task is defined as no more than three separate but related actions, except in those cases when a fourth action would "close" the series of actions. A task generally will not exceed about two minutes of actions requiring hard physical exertion.

The basic approach to job guides is to present all the information required to accomplish the task. The information must include:

Instruction -- Specific information on how to do the task, consisting essentially of directions to the user in terms of the actions to be taken.

Location -- The location of the equipment, controls, and/or displays upon which the action is to be taken or feedback is to be obtained.

Context -- The immediate surroundings of the equipment, display and/or control upon which the action is to be taken to allow ready identification of the item of concern.

Tolerance -- The criteria for assessing whether the response of the equipment is adequate. This criteria can be qualitative or quantitative, depending on the action taken.

In addition to the above, information must be provided to allow transition from one task to the subsequent task as well as from one activity to the subsequent activity. In the booklet format, the sequence information with respect to tasks is implicit and generally indicates that the user should follow the arrangement on the presentation. There are specific cases when the next task on a page is not necessarily the next task in time. Special instructions in the form of notes are presented to lead the user to the specific task of concern for these occasions. Branching instructions come under this category of sequencing information.

The data base should include selected support information which will allow the technician to prepare for jobs. This information is presented in the form of an input conditions page which provides all the information to allow the man to prepare properly, e.g., supplies, number of personnel required, special tools.

## 2. Level of Detail

As indicated previously, the information must include "how to do it" information or instructions as well as "what to do." The basic unit of information is a step which is comprised essentially of a given maintenance action, such as turn, adjust, rotate, push, pull. Thus a step is comprised of an action requirement taken against a particular portion of the equipment item of concern.

## 3. Unit of Presentation

Task is the basic unit of presentation. The task is that total set of information the user must read before he starts the task. It is designed to include only the amount of information which the man can comfortably and accurately retain for a short-term period, defined specifically as a 20 to 30 second time period. This is the time period required between the reading of the information and the actual initiation of the task. Pictorials also represent a unit of presentation, but a specific task will refer only to specific items on the pictorial. Therefore, in another sense, identifiers on the illustration are equivalent to the task as being the basic unit of presentation.

## 4. Readability

Three ground rules contributed significantly to improving the readability of the instructions. One ground rule limits the total amount of information which can be contained in a given task. This limit is in terms of number of steps as well as in number of words. A common syntax or sentence structure is used to assure that all instructions are presented in exactly the same manner with respect to the relative location of the nouns, verbs, and objects. The field test indicated that users eventually get to the point where they merely glance at the task of concern, and yet are able to comprehend the total instructions. This is due in part to the fixed syntax. A third important factor contributing to high readability is the use only of verbs on the preferred verb list. This

tends to decrease the ambiguity of certain verbs which may mean one thing to the writer but an entirely different thing to the user.

## 5. Unit of Storage

The page or frame is the basic unit of storage. In the case of the booklet, the size of the page is about 5 by 6-1/2 inches. All the information relevant to a maximum of seven tasks is presented on two facing pages. In the case of a larger sheet of paper, such as a page 8-1/2 by 10 inches, all the information will be presented on one page. This page is easily transferrable to a frame in the case of a visual device. In the case of an audio-visual presentation (which is not recommended at this time), the narrative information would be presented in the audio channel and the pictorial information on a visual channel. It is anticipated that future improvement will increase the amount of information which can be presented on one page. Condensation of information is important from a cost viewpoint. However, care must be taken to prevent degradation of the basic format characterisitcs which have resulted in the effectiveness of the job guides.

## 6. Scanning

Scanning refers to a quick review of an individual page for the specific information for a selected task. Scanning refers both to scanning of the relevant pictorial on a facing page and to the printed instructions. A limit is placed on both cases. In the case of pictorials for efficient scanning, the number of identifiers of concern is limited to seven, if the identifiers are presented in an unstructured manner. The total number can be increased if the arrangement of the identifiers on a pictorial can be structured. In the case of tasks, the concern with scanning is between tasks. When the user has finished one task, he then must search the page for the next task. It is important again that the total number of tasks which must be scanned to find the task of concern be kept to that amount which can be scanned effectively and accurately. This again is set at seven. As in the case of pictorials, for condensation purposes it may be possible to break the tasks up into groups of seven.

## 7. Unit of Package

An activity is the basic unit of package. An activity is defined as a maintenance function applied against a given equipment item, group, system or subsystem. An activity package then is comprised of all pages relevant to that activity arranged in the order of usage. A book or booklet is the next higher unit of package in the booklet system. In the case of a mechanized system, book would not be of concern. However, the frames must still be arranged by activity with the frames appearing in the order of usage. Any other arrangement would necessitate additional effort on the part of the user to locate the next page of concern for the given activity.

## 8. Access and Indexing

The accessibility of information depends upon whether the user has just been assigned a job or is within an activity. If he is within an activity, his retrieval is generally restricted to retrieval of task information and probably in gaining access to the next succeeding page. With respect to the task information, he has to scan no more than seven tasks to find the task he just completed in order to locate the next task. This time can be even shorter if he remembers the general location of the task. This is a relatively simple process and should not exceed three seconds. In fact, the PIMO field test results showed no case in over 1,000 instances where the user went to the wrong task.

The time required to turn a page, of course, is quite short. The booklet is designed to minimize cross-referencing and excessive branching. Consequently, when the user finishes the instructions on a given page, he generally finds the next task by merely turning the page. There are a few instances where he is referred to some later or preceding page. However, these instances are kept to a minimum to assure that accessibility of any page of information is extremely high. In those cases when references must be made to some other activity, the reference is made in terms of the title of the activity rather than a specific page

number. Thus, the page wherein the reference is made is not subjected to changes simply because of a change in the location of the activity data.

With respect to accessibility, the cross reference forces the user to always go to the index volume to find the activity of concern. Once he has the title or equipment nomenclature, the user scans the index volume for the title of concern. The index volume will lead him to the book within which the activity is concerned. Given the book, then, the user searches for the first page of the activity, using the table of contents to help locate that page. All this takes no more than 30 seconds, and in most cases significantly less time. Given the proper nomenclature, the search of the index volume is relatively short. Given the book number, and the books arranged in numerical order the search time for the book of concern is very limited. In most shops, the number of volumes kept in that shop will be relatively small, probably a maximum of six. Therefore the location of a given book will be quite simple. In fact, it is anticipated that within two to three months, the technicians in each shop will know which books contain the information of concern for any given assigned maintenance activity or job.

PIMO indexing has been designed to take into account the manner in which a technician is assigned to the job and the order in which he would look for the relevant information. Initially, the technician looks for the proper book of concern. Once he finds the book he searches for the activity of concern and subsequently, page by page. In any mechanized system, the search from the outset can be directed to a given page. Ordering of search for a printed system is an effective means of making the booklet system competitive with mechanized means for data retrieval.

The search for the book of concern can be limited to a search of the index volume. This volume has several different listings of all of the titles of activities to which a technician can be assigned. The different listings are provided to assure that however the manner in which the

job is assigned, the technician can easily scan the index volume to find the title of concern. Given the title, then only the book number is provided, and the technician searches the library for the book of concern. With the books arranged in numerical order, the search is relatively short. Given that he locates the book of concern, he then searches for the first page of the activity. This information is presented in the table of contents. This table is presented in matrix form. The rows are represented by equipment items in their proper indenture form. The columns are represented by titles of maintenance functions, e.g., Operational Checkout, Remove, Install, and Adjust. The technician searches for the equipment item or grouping of concern and then the proper function. The number entry identifies the first page of the activity of concern.

No other indexing is provided since once the technician initiates an activity, his search is limited to the next task of concern and the next page of concern. Consecutive numbering of tasks within the page and consecutive numbering of pages within an activity facilitate progress within the activity without undue search. Therefore, task and page number information generally are not provided in the index.

If and when a decision is made to mechanize the job guide data, one can anticipate that the access of information will also be highly automatic. Whatever means are used, care should be taken not to increase the amount of effort required on the part of the user to retrieve the information of concern from the approach described above. The retrieval of the next page should be limited essentially to one or two simple commands at the most. More time can be allowed in locating the first page or frame of an activity. However, the effort should not be significantly greater than the effort required to locate the next page or frame.

9. Portability

The portability of the data depends on the assigned activity or activities. In no case do we expect that the user would have to transport the entire

library. Portability is highest when the user is assigned a specific activity. In this case, he will be concerned only with one book which can be placed in the jacket of his fatigue uniform. There may be certain cases when the user may require more than one book, if he is assigned to a job comprised of a series of activities, e.g., resolve a given squawk. However, in nearly all cases, the "carrying" can be restricted to a given book. This can be assured by providing a library at the site of usage. The entire library can be contained in a relatively small suitcase, which can be dispatched to the aircraft as backup. If the user forgets to bring his book, or brings the wrong book, or is assigned a different activity, he can use the books in the suitcase library.

The entire library represents the worst case of portability. Even here the weight and size are sufficiently low to allow one man to carry the suitcase to and from the aircraft.

It will be difficult for any mechanization concept to approach the portability of the booklets. Thus, a decision to mechanize will depend on factors other than portability, such as storage and ease of update and retrieval. Retrieval becomes a problem only when the entire data base must be accessible at all times. This is not the case in aircraft maintenance. It is expected that mechanization will degrade portability while improving the factors such as storage and ease of update. It is cautioned that if the portability characteristic is degraded too much, it can overcome whatever advantages accrued in the areas of storage and/or ease of update.

10. Reliability

Since no equipment is involved, reliability refers primarily to the durability of pages for the booklet system. Paper durability is not too great in a harsh environment. Booklets are susceptible to the adverse environment to which any paper system is vulnerable. Vulnerability to the environment can be decreased somewhat by using special paper, but normally this is accomplished at the sacrifice of cost and

weight. In such harsh environments as the tropics or arctic, it may be necessary to utilize special materials resistant to the environment in spite of the cost and weight involved.

11. Resolution

The resolution of printed matter in good ambient illumination represent the best resolution one can expect. When devices are used, this resolution is normally degraded. The question is, how much can it be degraded without affecting visibility or readability. So long as these two factors are not affected adversely, a degradation of resolution is acceptable. The printed matter has the disadvantage that its readability is dependent on ambient illumination. Thus, it is very difficult in bad light and requires an external source of illumination. This could be a handicap when working at night in normally unlit areas. This would require the user to have a source of light, such as a flashlight. It should be noted that this other source of light would also be required to allow him to see the item he is maintaining.

12. Storage

As indicated previously, one copy of all volumes can be placed in a suitcase. Therefore, the space required to store a copy of the booklet system is quite small. Relevant books are kept at each shop, and the number of books required for any given shop is expected to be no more than six. At least one library should be kept at the aircraft, whether dispatched specially to the aircraft or carrier on the aircraft at all times. The organizational maintenance squadron requires multiple sets of the library, since their work is not specialized.

Despite the small size of a booklet, storage could become a problem when the number of systems which have to be maintained by a given base increases significantly. This could require the base to maintain the library for each system. The update process would be simplified if all books were centrally located. Update is more complicated with books stored at different locations. However, this problem is no greater than what is currently being incurred in storing and updating technical orders.

### 13. Other Usability Factors

The booklets are very useful in that they can be carried quite easily, and the binding used will allow the pages to lie flat. When in use, the booklet can be placed almost anywhere that there is available space. The booklet is still a paper system and therefore is susceptible to lighting conditions, the paper becoming torn during rain, and the paper turning under wind conditions. However, it should be noted that the small size of the booklets will allow the user to protect it quite effectively from adverse environmental conditions.

## B. TROUBLESHOOTING AIDS

The basic approach for presenting information to support trouble-shooting was adopted from the SIMMS package. Although the format has been adopted, it is part of the PIMO Job Guide system being recommended for immediate applications. The basic characteristics of this portion of the system can be described in the same manner in which the maintenance instructions were described.

### 1. Information Content

Information provided in the MDC's is also at the task level and includes instruction, location, context, and tolerance. To this extent, the MDC's do not differ from the maintenance instructions. However, the sequence of tasks is left to the discretion of the user. To support his decision-making, two additional items of information are included as critical to this mode of operation. These are the equivalent entities within a given system and the dependencies of these entities. These dependencies are used by the reader to determine the troubleshooting strategy and sequence of test tasks.

The data base includes other supportive information such as input conditions, operations descriptions, and usage instructions. The input conditions serve the same purpose as the input conditions of the maintenance instructions in that they provide the information necessary

to allow the technician to prepare for the troubleshooting job of concern. The operational descriptions are provided as a support of training.

2. Level of Detail

This is another important parameter which differentiates between the maintenance instructions and the troubleshooting aids. The level of detail provided in the troubleshooting aids specifies what tasks must be accomplished but do not describe how the task is to be accomplished. The "how" information is provided in the checkout tasks in the corresponding maintenance instructions. Therefore, the "how" information is still contained in the total data base. The task information at the "what to do" level is assumed to be satisfactory for the experienced technicians who must accomplish the troubleshooting jobs.

3. Unit of Presentation

The task and the maintenance dependencies associated with the given task are the basic unit of presentation. In one sense the MDC provides a pre-tracing of schematics for each checkout task. At any given "reading," the user is concerned only with the dependency for a given task. Given a no-go situation, he may examine the entities on the dependencies for some previous task. However, these tasks are examined again as a unit, i.e., dependencies related to the task of concern.

4. Readability

A version of the sentence structure or syntax used for maintenance instructions and the preferred verb list also applies to the checkout tasks included in the MDC's. These tasks, as mentioned above, provide a way of structuring the basic unit of presentation. Furthermore, it is important that the user can easily read the task information to assure that he takes the proper actions. If improper actions are taken for a task of concern, the technician performing troubleshooting may become confused since the dependencies may not be as described on the MDC for that task.

5. Unit of Storage

The MDC's and the supportive information are placed on pages 11 x 17 inches. This is a compromise in that the SIMMS packages are normally put on larger sheets. However, careful examination of the work situation for the C-141 indicate that there are many cramped quarters wherein large pages would be extremely cumbersome. Each page contains a considerable amount of information, since the MDC approach provides a combination of proceduralized troubleshooting and a schematic type of system representation.

6. Scanning

The MDC is arranged in quadrille form with varying line widths. The basic columns are the equipment entities. The rows are basically dictated by the checkout tasks. Subsets of rows are provided within each task to allow different expression of dependencies. With this type of a quadrille arrangement, two types of scanning are involved. One scanning is in finding the next task of concern. This scanning is limited to the scanning of the procedural column only. The second type of scanning is in seeking the equipment responses and the dependencies. The initial scanning is in seeking visible responses of equipment items. This scanning is facilitated by symbols which will allow ready identification of those responses which are in fact, visible. Subsequent scanning is required when a no-go condition is discovered. This scanning is facilitated by lines which lead "backwards" to the next preceding equipment item upon which the visible response is dependent. Lines and special symbols reduce the scanning problem to a minimum.

7. Unit of Package

The basic unit of package is either a system or segment of a system which can be treated as a functional entity. This is essentially a troubleshooting unit in that once the problem is isolated to this unit, all of the troubleshooting is restricted to within the unit. Normally,

the segment is a subsystem of a major system on the aircraft. Usually, a number of these system segments or subsystems are bound together in a book.

## 8. Access and Indexing

As in the case of maintenance instructions, access characteristics differ depending upon the work situation, i.e., whether the user is within a troubleshooting activity or is looking for the information at the beginning of the job. Once troubleshooting is initiated, access is limited to the retrieval of the next task and/or the next page. This access is relatively simple, since it is strictly visual and/or a matter of turning the page. Gaining access to the proper information when first assigned the job is somewhat more difficult. In this case, the user must find first the proper book and then the proper first page for the troubleshooting set of concern. The indexing volume guides the user to the proper information set. It can be accomplished well within the required thirty second maximum specified for transferring from one activity to another. Since normally several subsystems or system segments are included in a book, once the proper book is identified the user must locate the segment of concern within that book. As in the case of maintenance instructions, given that the proper book is located, location of the specific segment within that book is quite simple.

Troubleshooting is generally initiated from "squawks" reported by the air crew or other members of the ground crew. With respect to the ground crew, the "squawk" generally results from other checkout activities. Squawks can be broken into two basic categories, i.e., squawks reported in terms of system indicators or squawks reported in terms of system in trouble. The index volume was constructed to allow the technician to rapidly correlate the squawk information to the books. The index volume provides an arrangement of systems in alphabetical order and arrangement of indicators in alphabetical order. This is based on the fact that most squawks relate to the indicators. However, the reporter may not know the proper nomenclature for the

indicator. Therefore, one arrangement provides an illustration with the indicators identified. Given that he knows which indicator is involved, he can then use the index column to find the specific nomenclature which, in turn, identifies the volume of concern. When the squawk is by a system, e.g., Doppler radar will not work, the arrangement of systems by alphabetical order should greatly facilitate the location of the proper troubleshooting information.

9. Portability

Generally, the total amount of data required for a given troubleshooting job is limited to one book. This book is 11 x 17 inches in size and normally around 1/2 inch in thickness. It is relatively easy to carry although not as simple as the booklets. There may be certain cases when more than one book will be required when the problem transcends a given system segment. For example, the problem may be in the input source rather than within the system of concern. This will require tracing the problem to the input source which may be located in a separate book. However, the portability characteristic need not degrade significantly if a complete library is dispatched to the aircraft. A complete library of the troubleshooting aids can be located in a suitcase similar to the size used for the maintenance instruction booklets. This will allow the user to immediately find the related troubleshooting aid book on the job, rather than having to go back to his shop to pick up another TSA. In the greatest percentage of the cases, the troubleshooting will be limited to the book initially selected by the user from his own library.

10. Reliability

The durability of the pages is considerably higher than the pages used for the booklets. Special material should be used to allow the technician to write on the MDC's and subsequently erase the markings without affecting the basic MDC. These materials are more expensive and heavier than the normal paper used. Due to the weight of the materials, binding becomes a problem unless given careful attention.

11. Resolution

The resolution of the TSA's are essentially the same as the booklets and represent the best possible resolution in good ambient illumination. Visibility is a problem in low ambient illumination conditions unless flashlights or other sources of illumination are made available.

12. Storage

As indicated previously, the entire TSA (one copy each) for the C-141 can be stored in a suitcase. Only the relevant books (generally one) will be kept at any given shop. An entire library should probably be kept in the aircraft and at the OMS. To assure configuration control, special color codes or other identification schemes can be used to assure that the books are not misplaced. As in the case of the maintenance instructions, the TSA's are quite compact and do not require much space.

## SECTION V

## CHARACTERISTICS OF THE DEVELOPMENT AND UPDATE SEGMENT

There are five basic elements involved in the development and update segment. These elements are:

Preparation of the materials,
Development of the materials,
Production of the materials,
Control of the development and production efforts,
Updating the materials.

Each will be discussed in a general sense.

### A. PREPARATION OF THE MATERIALS

#### 1. Nomenclature

Before any effort is initiated, it is important that the language used to communicate be firmly established. One critical aspect of language is the nomenclature of both the equipment items and functional entities. A second important aspect is the verbs to be used in the final product. Just as important is the definition of terms used in communicating between the different members of the team. The types of terms which have to be clearly defined are signal characteristics, parameters, etc.

#### 2. System Partition

Proper partitioning of the system into subsystems and segments for troubleshooting units is extremely important to the proper development of the troubleshooting aids. Partitioning is also important to the maintenance instructions to assure a common and acceptable equipment indenture scheme. This relates to the previously mentioned problem of nomenclature. A common and comprehensive indenture scheme is important to assure that only one name is assigned to each equipment item. The partition should be taken to the level of subsystem or

system segment. Within each subsystem or system segment, all of the equipment items comprising that segment should be clearly defined.

3. Function by End Item Matrix

This matrix should be developed immediately following completion of the system partitioning. The matrix will help to identify the total data base required as well as provide a structure for determining whether specific activities should or should not be covered in the data base. The functions refer to maintenance functions which are to be applied against an equipment item of concern. To properly define the data base in accordance with cost effectiveness practices, the anticipated frequency of demand for each cell should be defined. This information can then be combined with the criteria for inclusion or exclusion of informational items in the data base to finalize the total data base. The function by end item matrix will also be an integral part of maintaining information about configuration and production process for control purposes.

4. Collection of Source Material

Source material should be collected and organized to assure easy identification and to assure availability during data development. As will be noted later, each source material is coded to assure proper control of the update process. Therefore, common method of identifying source material is necessary. Collation of the source material or at least identification of all relevant source material is necessary to affect this identification. Source materials are anticipated to be engineering data including schematics, specifications, and results of analysis such as reliability and maintainability analyses. In addition, the source material could include vendor supplied manuals or such manuals as are already available.

5. Guidelines and Specifications

Specifications for the output products are included in this report. However, it is erroneous to assume that specifications will be adequate

to assure proper data production. Specific guidelines should be provided for each major function in the development and update process. These guidelines will assure that proper capabilities are applied to the process as well as standardizing the development process. Effective guidelines will allow utilization of a lower level of personnel than is generally used in development of data. Higher level personnel are required to analyze in detail the function required to develop the materials, to translate the analysis, and to give specific instructions to the individuals who will be implementing the function.

### 6. Training/Orientation

The development of job guide materials is highly affected by the attitude of the individuals developing the materials. Orientation towards acceptance of the problems of the user is very important. Training of the specific techniques utilized to develop the materials is relatively straightforward. Training or orientation of the individuals to adopt the attitude that the most important criterion is the usability by the users is a more difficult task. Without such an attitude, the quality of the materials could suffer significantly due to the fact that the specifications can never be written to cover every eventuality.

## B. DEVELOPMENT OF THE MATERIALS

### 1. Definition of a Step

It is reasonable to assume that information at the task level will be provided as part of the source material. This is provided in task analyses which the Air Force normally procures as a data item. For each maintenance activity, the first step in developing the materials will be in defining specific steps which are to comprise the tasks. Clear definition of steps is very important to assure that the instructions are explicit and to assure that the total information associated with a given task is provided. This total information must include the illustrations and identification of specific items on the illustration. It

also should have information generally not provided in maintenance analysis products. Close coordination must be maintained with those developing IPB's and engineering drawings to assure that the tasks provided from maintenance analysis are compatible with configurations assumed for the illustrated parts and/or engineering drawings.

2. Validation/Verification

The validation/verification process in concept is basically no different from the process currently applied to the technical orders. However, this applies primarily to the validation/verification of the technical aspect of the materials. Included in the validation/verification process should be the usability aspects of the materials. This can only be accomplished effectively by working with personnel representative of the final group of users. Engineers and specially trained technicians are not best at assessing the usability of the materials. It is important that a sufficiently high priority is assigned to the validation/verification of the materials to assure that all procedures are actually tried on the equipment or an exact representation of the equipment of concern. The validation/verification should be accomplished by personnel other than those responsible for generating the materials.

3. Formatting

The formatting process itself is relatively straightforward if the steps described in this document are followed. Creativity in formatting should be highly discouraged since the desire is for every page to manifest the same basic format characteristics. If a change is to be made, this should be determined by the analyst defining the steps or the final quality control which is looking at the data in terms of usability by the technicians. The basic process of formatting must be in strict accordance with the specification and guidelines.

4. Typing/Illustration

The typing/illustration required for the job guide materials are no different than that required for conventional technical orders. The

one exception is that more illustrations are generally used in the job guide material than in the current technical orders. However, a large percentage of the illustrations (somewhere near 80 percent) are duplications of original art. These illustrations need not be redrawn.

### 5. Quality Control

Quality Control must be concentrated on the output of the formatting function before it is sent for validation/verification. Two types of quality control are of concern. One type is to determine whether products adhere to the specifications. This is a relatively straightforward quality control. The second type is with respect to usability of the information by the user. This is the more complex and abstract type of quality control in that the reviewer has to place himself in the position of the user and assess the materials accordingly. This type of quality control frequently results in special adaptations of the specifications for the material of concern. Thus, interpretation of the specifications for the special applications will be accomplished by quality control personnel.

## C. PRODUCTION

Production of job guide materials is essentially no different than production of the current technical orders.

## D. CONTROL OF DEVELOPMENT AND PRODUCTION

An integral part of the development and update segment is the application of production control techniques in maintaining control of the data and the development process.

### 1. Role of the BTDS

The Basic Technical Data Storage System is the primary supportive tool used to help keep track of the data as well as maintain production records. The information is extremely useful in quickly identifying the pages of the job guide materials affected by any changes of the

source material. In addition, the BTDS, through its production records, allows a ready measurement of progress in producing material as well as identifying the location of specific material packages. Thus, the BTDS is the basic management information system for controlling the development and production of job guide materials.

## 2. Stations

The functions required to develop and produce job guide materials can be assigned to specific stations. These are stations that all materials will flow through and include: prevalidation, formatting, validation, quality control and review, production, and distribution functions.

## 3. Packages Flowing Through the Stations

The maintenance activity is treated as the basic package which flows through the stations. All of the job guide materials relevant for a given maintenance activity are treated as one package. This package is assigned a special number and logged in the BTDS. The time that the package enters a given station and leaves a given station are also entered in the BTDS. Whenever a problem is noted in the package, this problem is expressed in terms of numbers of pages affected. This information is also stored in the BTDS.

## 4. Measurement Parameters

Two measurement parameters can be effectively used to help control the development and production process. One parameter is the time in a given function or station. The second parameter is error rate. Both can be measured with the BTDS by keeping records of packages as they flow in and out of stations. For example, error rate can be measured since review and quality control are functions for which records are also kept. Therefore, a package "bouncing" from review back to one of the generation functions, will be identified in the BTDS. Thus, error rates can be established for each individual as well as for the station.

### 5. Location of Individual Packages

The method of record keeping discussed above for packages flowing through the stations will also be useful in identifying the specific location of an individual package. This identification is very important for production control since packages can become lost or changes must be made on a package in process.

## E. UPDATE

The process for updating is the same as the process for the development and production of initial data. One exception is that update generally requires identification of those pages which must be changed as a consequence of changes of equipment or a change request submitted from the field. Therefore, ready identification of all affected pages is an important aspect of the update process. The BTDS allows such ready identification since it stores all information with respect to the relationship between source material and the final job guide materials as well as the relationship between different segments of the job guide materials. Therefore, the BTDS can print out the relevant or potentially impacted pages which can be examined in detail by the analyst. Once the identification is made, the process of actually making the change is essentially the same as the development and production of initial materials. The problem of incorporating the changes in the book that have been noted for T.O.'s also applies to the job guide materials when packaged in booklet form. It may be possible to send new books out and have the users ship back the old books which will be updated in the "plant." This technique is similar to the one generally used for microfilms. Whether it will in fact, apply to booklets remains to be seen, but it is an alternative subject to consider.

## SECTION VI

## INTERFACING SYSTEMS IMPLEMENTATION

PIMO is a proven effective information system. However, its power cannot be realized unless the larger system (the maintenance system) in which it operates is modified properly. The major subsystems of the maintenance system which are impacted by PIMO are: the maintenance management, personnel, and training subsystems. The impact of PIMO on these subsystems is discussed below.

### A. MAINTENANCE MANAGEMENT SUBSYSTEM

At all Air Force bases, a significant fraction of the maintenance personnel are unskilled 3-levels. With the training these inexperienced people receive and the maintenance technical data they now have to work from, maintenance managers are properly reluctant to assign them to work independent of experienced people. With maintenance technical data in the PIMO format, the inexperienced technician works efficiently and reliably with only normal supervision. Maintenance managers must be willing to assign inexperienced people in order to gain the benefits of PIMO. An extensive promotional effort will be required to convince maintenance managers of the correctness of the assignment of inexperienced personnel.

Maintenance managers must establish and keep at a high state of performance a quality control system for approval of work performed by inexperienced technicians. Air Force doctrine now requires any work performed by 3-levels be approved by specialists. This doctrine is directly applicable to PIMO. It makes efficient use of specialists and facilitates the use of non-specialists.

A continuing program of motivating personnel to use the PIMO maintenance technical data is required. This promotional effort is related to and ought to be coordinated with the program to convince maintenance managers to assign inexperienced technicians. The maintenance

managers will eventually see the benefits of the new assignment rationale while the technicians may not be able or willing to recognize the need to continue using the PIMO data. Thus, the program to motivate use must be continuing while the assignment campaign can be dropped eventually.

The promotional campaigns should be initiated prior to introduction of any PIMO data to a base. It is unimportant how many systems have the new data. Before the first set of data is supplied to a base, the campaigns must start. It is mandatory that the maintenance managers be prepared to accept and use the PIMO data properly. If allowed to keep old habits when the new data is introduced, it will be much more difficult to change those habits later.

To accomplish the maintenance management tasks necessary to maximize the benefits of PIMO, it is recommended that each base select a single individual to spearhead the changeover. This individual should be an open-minded, reasonably far-sighted man who recognizes and accepts the benefits of PIMO. Preferably he should be a recognized expert on maintenance of the systems of concern and highly regarded by the maintenance staff. Such a man is invaluable for other duties as well, but his assignment here will be highly beneficial.

## B. PERSONNEL SUBSYSTEM

The personnel profile of Air Force maintenance staffs is heavily weighted with unskilled individuals. This condition exists in large part because the skills received in training are highly marketable outside the military. Commercial aviation is currently growing at a high rate. Thus, the demands for skilled aircraft mechanics is also growing at a high rate. Under these conditions, it is unlikely that the retention of skilled personnel will improve materially in the near future. PIMO makes it practical to get meaningful work out of the unskilled. But there remains a need for the skilled technicians. The introduction of PIMO should reduce the need for extensive re-enlistment

campaigns. The emphasis can be shifted to identification of those technicians who are genuinely interested in an Air Force career. Specialist training can be given on the basis of a given term of service after the training. Generally, assignment to specialist training would be expected to come at or near the end of the first enlistment. For exceptionally able individuals, it might come earlier. The goal is retention for a reasonable period of the specialist after training.

The effect of this strategy is to shift downward somewhat the overall skills profile of the maintenance staff. Such a shift is beneficial from a cost standpoint. At the same time, maintenance reliability is improved. The downward shift in skills will cause some concern among maintenance managers. The shift will undoubtedly take a lengthy period to complete, but its existence will be recognized early. Consideration must be given to the effect on morale of the existence and perception of the downward skills shift.

The formal training required also varies depending upon how long the object system has been in the Air Force inventory. For totally new systems, all training should be oriented towards use of the Job Guide. Where the system has recently been introduced to the Air Force and is still being supported extensively by contractor personnel, standard technical orders have most likely been prepared. The Air Force technicians using these standard technical orders will also get extensive support from contractor personnel. Thus, they can get by without job guides and associated training. However, all technicians who do not have the benefit of contractor support should have Job Guide oriented training. Data in the PIMO Job Guide format should be available immediately for them when assigned operational positions. Technicians in the PIMO field test expressed high interest and favor in having Job Guide data when assigned to a new system.

Formal training for technicians already in the field on mature systems can be quite limited. Brief classroom orientation and on-the-job orientation should be adequate.

## C. INTERFACING SYSTEMS IMPLEMENTATION CONCLUSION

From the above discussion, it is clear that the effect of the Job Guide on the entire aircraft maintenance system is considerable. The interfacing systems must be adopted to the job guide approach if its maximum benefits are to be realized. The effort will not be small, but the return will more than justify the effort.

## D. TRAINING

Introduction of Job Guides will have a major impact on training. Fewer technicians will need specialist training. The training emphasis for specialists will be heavier on troubleshooting and lighter on the other maintenance functions. In addition, specialists must develop skills to evaluate the work of non-specialists. A thorough evaluation of the impact on training of use of Job Guides was not within the scope of Project PIMO. The benefits of the Job Guides are such that they should be introduced to Air Force systems immediately. Training of non-specialists in the use of Job Guides will support immediate introduction of them to the Air Force Maintenance system. After that, specialist training can be adjusted as required.

The formal training required by totally inexperienced technicians before they are able to work effectively is quite limited. Major elements of learning required are: aircraft and maintenance terminology, orientation to specific aircraft, use of standard tools, general safety considerations, familiarization with the format of the Job Guide. These elements are discussed briefly below.

### 1. Aircraft and Maintenance Terminology

The terminology used in the PIMO Job Guides is identical with that now used in maintenance training. Wherever more than one word or phrase is used for the same piece of hardware or the same physical act, the single, best word or phrase was selected for PIMO. Thus, the training currently given technicians in aircraft and maintenance terminology is more than adequate for when PIMO Job Guides are used.

## 2. Use of Standard Tools

Technician trainees must be taught how to identify and work with standard tools. It is not necessary for them to be trained in every maintenance task for which they may be called upon to perform. However, they must be trained over the range of tasks. The main purposes of this training are to develop motor skills and to build the technician's confidence. In the process of learning use of standard tools, the trainee also will become familiar with the hardware for which he has been given terminology instruction.

## 3. General Safety Considerations

The PIMO Job Guide has specific safety precautions throughout each booklet. These are presented in language sufficiently clear that technicians have no trouble understanding. However, there are general safety considerations which should be known and understood by all without recourse to a job guide. Repeated reference to these general safety items would tend to obscure the specific safety considerations in a booklet. Thus, the general items must be included in formal training. It is likely that increased attention to this subject will be required with the shift downward in average skill level.

## 4. Familiarization with the Format of Job Guides

It is mandatory that technicians be provided formal orientation to the job guides. With new trainees this comes as a matter of course. But for technicians who have already had basic mechanic training, this orientation might be over-looked. The purpose of this training is two-fold. Firstly, the job guide format is different and could be slightly confusing to technicians who have already been trained. This is not because of any inherent difficulty, but rather just because it is different from the standard technical order. Secondly, human nature is resistant to change. Unskilled technicians will not be as ready to accept the job guide as they can and should be until they have learned how it works and what it will do for them.

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13. ABSTRACT

This report describes the latest phase in the program to develop and evaluate PIMO (Presentation of Information for Maintenance and Operation); a job guide concept applied to maintenance. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Three immediate behavioral effects were expected: 1) reduction in maintenance time, 2) reduction in maintenance errors, and 3) allow usage of inexperienced technicians with no significant penalty. Experienced and inexperienced Air Force technicians performed maintenance on C-141A aircraft using PIMO Job Guides presented in audio-visual and booklet modes. Performance was measured in terms of time to perform and procedural errors. The performance was compared with the performance on the same jobs by a control group, i.e., experienced technicians performing in the normal manner. The following conclusions were drawn from the test results: 1) after initial learning trials, both experienced and inexperienced technicians using PIMO can perform error-free maintenance within the same time as experienced technicians performing in the normal manner, 2) inexperienced technicians perform as well as experienced technicians when both use PIMO, 3) there is no significant difference between audio-visual and booklet modes, 4) the users revealed an overwhelmingly positive reaction to PIMO, and 5) the performance improvements provide the capabilities to significantly improve system performance defined in terms of departure reliability, time-in-maintenance, and operational readiness. This report also presents a description of the recommended operational system, specifications and guidelines for PIMO format development, including troubleshooting.

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| Job-oriented Guides | | | | | | |
| Aircraft Maintenance | | | | | | |
| Troubleshooting Aids | | | | | | |
| Field Test of Maintenance Aids | | | | | | |
| Audio-visual Presentation, Maintenance Data | | | | | | |
| Maintenance Dependency Charts, Preparation of | | | | | | |
| PIMO, Programmed Information for Maintenance | | | | | | |
| Technical Data, Reformatting of | | | | | | |
| Technical Data, Specifications for | | | | | | |
| Technical Orders, Comparison of (with PIMO) | | | | | | |
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